Brief Report

Effects of Deep Pressure Stimulation on Physiological Arousal

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MeSH TERMS

- adaptation, physiological
- arousal
- autonomic nervous system
- pressure
- touch

Deep pressure stimulation has been used in therapeutic practice because of the assumption that it changes physiological arousal. The purpose of this study was to test the effects of deep pressure stimulation, applied with a Vayu Vest (Therapeutic Systems), on both autonomic arousal and performance in a normative adult sample. A repeated-measures, repeated-baseline design was used with participants completing a performance test before and after deep pressure application. A convenience sample of 50 adults participated in the study. Results showed that wearing the Vayu Vest for even short periods of time reduced sympathetic arousal and non–stimulus-driven electrical occurrences. Concomitant increases in parasympathetic arousal were found. Performance improvements were noted after wearing the Vayu Vest, potentially because of changes in arousal. We conclude that deep pressure stimulation is capable of eliciting changes in autonomic arousal and may be a useful modality in diagnostic groups seen by occupational therapy practitioners.

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Deep pressure touch has been used as a therapeutic modality in occupational therapy practice because of the assumption that it can produce a calming effect through changes in physiological arousal (Kimball et al., 2007). This assumption is grounded in the literature base of several areas of research, including sensory integration (SI) theory. In SI theory, calming effects are believed to result from modulation of central nervous system processing of sensory information (Ayres, 1972). Deep pressure touch, carried by the dorsal column system, is believed to influence reticular formation activity, with descending reticular pathways having a direct influence on autonomic activity (Angeles Fernández-Gil, Palacios-Bote, Leo-Barahona, & Mora-Encinas, 2010). It has been proposed that deep pressure touch influences both parasympathetic activity (through increased vagal tone, reflecting increased parasympathetic activity [Field, Diego, & Hernandez-Reif, 2010]) and sympathetic activity (through reduced activation of the stress response, reflecting reduced sympathetic activity [Kimball et al., 2007]).

Evidence is scarce for the use of deep pressure touch in clinical practice, and the research that does exist has used various modes of application (e.g., weighted vests, brushing, Squeeze Machine [Therafin Corporation, Frankfort, IL]) without the use of objective physiological measures (Edelson, Edelson, Kerr, & Grandin, 1999; Fertel-Daly, Bedell, & Hinojosa, 2001; Hodgetts, Magill-Evans, & Misiaszek, 2011; Lin, Lee, Chang, & Hong, 2014; VandenBerg, 2001; Withersty, Stout, Mogge, Nesland, & David Allen, 2005). Research on deep pressure use has been done almost exclusively with children, with only two studies to date involving adults (Mullen, Champagne, Krishnamurty, Dickson, & Gao, 2008; Withersty et al., 2005). In addition, no studies to date have comprehensively examined the effects of deep pressure application in a typical population, indicating a need to establish the standard deviation and range of physiological and performance outcome measures in a typical sample. The purpose of this study, therefore, was to test the effects of deep pressure stimulation, applied through a Vayu Vest (Therapeutic Systems, Amherst, MA), on both performance and autonomic arousal in a normative adult sample. We hypothesized that deep pressure input would decrease sympathetic arousal, increase parasympathetic responses, and improve measures of performance.

Method

Design

We used a cross-sectional, repeated-measures, repeated-baseline design that included description and analysis of outcome measures. All procedures were approved by the university's internal review board before participant recruitment. Consent and assent procedures were completed for all participants.

Participant Recruitment

Participants between ages 18 and 40 yr were recruited from the normative population through flyers and word of mouth. Participants were excluded if they were pregnant or thought they might be pregnant, had a cognitive or intellectual impairment, or had a motor impairment that would prevent them from donning or inflating the vest. Vest sizes available for the study were a youth large, adult small, adult medium, and adult large. Participants who did not fit these sizes (either too small or too large) were excluded. Participants had to be capable of following directions in English.

Procedures

Data were collected in a controlled laboratory setting with dimmed lighting (approximately 20 lux). Before the study protocol began, electrodes were applied to participants' chest, back, and palm for collection of physiologic data, and participants donned a deflated Vayu Vest. All straps were adjusted to ensure correct size and fit. Physiological data were collected during seven 3-min epochs (Figure1). As can be seen in Figure 1, baselines preceded both testing epochs and the Vayu Vest epoch. During the three baselines and one recovery epoch, participants were asked to sit quietly for 3 min. During test epochs (Test 1, Test 2), participants engaged in an electronic game (described later). The Vayu Vest was inflated after Baseline 2, before starting the Vayu Vest epoch, and deflated after this epoch, before Baseline 3. Participants remained seated during the entire protocol.

Intervention

The Vayu Vest is a wearable, noninvasive, and nonpharmacological medical device. The internal bladder and hand pump allow the vest to be inflated to levels desirable for each wearer. As noted previously, the vest was inflated after Baseline 2, before starting data collection for the Vayu Vest epoch. For each participant, the examiner demonstrated how to inflate the vest with the hand pump and proceeded to inflate the vest until the participant noted feeling some pressure. The hand pump was then given to the participant, who was told to continue inflating until it felt like "a firm hug." The vest was worn during the 3-min Vayu Vest epoch and was then deflated before initiating Baseline 3.

Measures

Physiology Measures. Wet gel electrodes were placed on participants' chest and back to collect heart rate and respiration data; silver–silver chloride electrodes were placed on thenar and hypothenar eminences of the nondominant hand and secured with self-adherent wrap to collect electrodermal activity (EDA). Data were collected on a personal digital assistant worn by the participant, sent wirelessly to the computer, and monitored throughout the study to ensure data integrity. BioLab Acquisition Software (Mindware Technologies, Gahanna, OH) was used for data collection; analysis was done using HRV (heart rate variability) and EDA Skin Conductance Analysis Software (both from Mindware Technologies). Physiological variables of interest in this study included changes in tonic skin conductance level (SCL) scores from the beginning to end of a single epoch, number of nonspecific skin conductance responses (NSRs) within an epoch, and respiratory sinus arrhythmia (RSA).

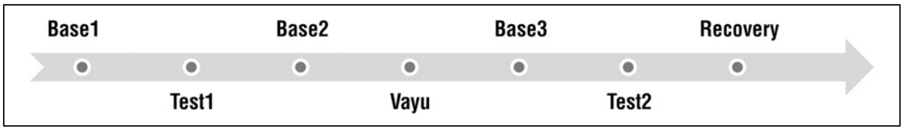

Figure 1. Repeated baseline procedures used for data collection.
Note. Base1 = Baseline 1 epoch; Base2 = Baseline 2 epoch; Base3 = Baseline 3 epoch; Recovery = final epoch, or final baseline data collection point; Test1 = first administration of Moron Test; Test2 = second administration of Moron Test; Vayu = epoch when Vayu Vest was inflated.

Performance Measure. Performance was measured by counting the number of errors made on the brainteaser game Moron Test (DistinctDev Inc., Seattle, WA). In the game, players are given a series of increasingly difficult tasks to complete or questions to answer; problems include calculating, matching, memorizing, sequencing, and identifying. Multiple versions, or sections, of the game have been developed; each section has more than 100 steps and more than 45 tasks.

The game was played by all participants on an iPod touch (Apple Corporation, Cupertino, CA). Participants randomly selected one of six versions of the Moron Test to play at Test 1 and Test 2. To minimize the effects of learning, we did not allow participants to play the same version of the game for both test sessions. Participants were instructed to continue playing the game for the entire 3-min epoch, even if they made multiple errors and had to start from the beginning of the game. Errors were tallied by the examiner each time the error buzz sounded from the iPod.

Statistical Analysis

Three separate repeated-measures analyses of variance were conducted for each physiological variable of interest (tonic SCL change, NSRs, and RSA); scores were examined across all seven epochs. Because of the greater percentage of women in the study, gender entered into all models as a covariate. Mauchly's test statistic was applied to all physiologic data and indicated that the condition of sphericity was violated in all cases. As such, degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity (Abdi, 2010). A paired t test was used to compare pretest and posttest scores on the Moron Test. Bonferroni corrections were used to correct for experimentwise error. For all analyses, α level was set at $p < .05$.

Results

Sample

Fifty adults between ages 18 and 35 yr (mean [*M*] age = 24.5 yr, standard deviation [*SD*] = 4.14) participated in this study. Seventy percent of the sample was female (26% male, 4% unreported). One-quarter of the sample (25.5%) was currently being treated for a psychological condition, a statistic commensurate with national averages (Kessler, Chiu, Demler, Merikangas, & Walters, 2005). The most commonly reported conditions were anxiety, depression, and attention deficit hyperactivity disorder (ADHD). On the Adult/Adolescent Sensory Profile (Brown & Dunn, 2002), the majority of participants scored *similar to most people* in all four quadrants of sensory processing: low registration (64.4%), sensation seeking (71.1%), sensory sensitivity (73.3%), and sensation avoiding (71.1%).

Changes in Skin Conductance Level

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(20) = 78.28, p < .001$; therefore, degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity ($\epsilon = 0.58$). SCL values are reported in microseimens, a unit of measure that reflects electrical activity on the skin; difference values were determined by subtracting SCL values at the end of the 3-min epoch from SCL values at the start of the 3-min epoch; lower scores reflected a greater decrease in skin conductance.

The results showed that changes in SCL differed significantly across epochs, $F(3.47, 17.92) = 6.571$, $p < .001$. The effect of gender on the model was nonsignificant ($p = .595$). SCL change scores were the lowest during the Vayu Vest epoch ($M = 2.928$, $SD = 3.3$; Figure 2), indicating that the greatest reduction in SCL was seen within the 3 min the Vayu Vest was inflated. Post hoc tests using the Bonferroni correction revealed that the Vayu Vest epoch differed significantly from Baseline 1 ($p < .01$), Test 1 ($p < .01$), and Test 2 ($p < .01$).

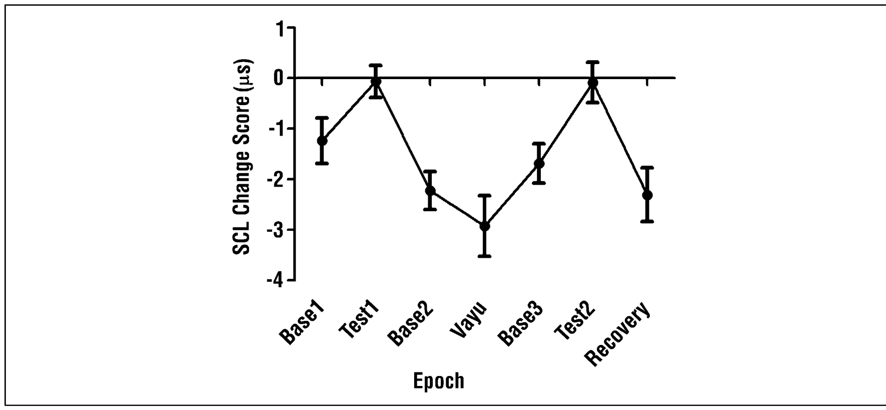

Figure 2. Changes in SCL scores across epochs.
Note. Error bars indicate standard error of the mean. All epochs were 3 min in length. Base1 = Baseline 1 epoch; Base2 = Baseline 2 epoch; Base3 = Baseline 3 epoch; Recovery = final epoch, or final baseline data collection point; SCL = skin conductance level; Test1 = first administration of Moron Test; Test2 = second administration of Moron Test; Vayu = epoch when Vayu Vest was inflated.

Nonspecific Skin Conductance Responses

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(20) = 90.45, p < .001$; therefore, degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity ($\epsilon = 0.51$). The number of NSRs differed significantly across epochs, $F(3.06, 17.8) = 75.77, p < .001$. The effect of gender on the model was nonsignificant ($p = .698$). The number of NSRs was lowest during the Vayu Vest epoch ($M = 7.08$, $SD = 6.9$; Figure 3). Post hoc tests using the Bonferroni correction revealed that the Vayu Vest epoch differed significantly from Test 1 ($p < .001$), Baseline 3 ($p < .05$), Test 2 ($p < .001$), and recovery ($p < .001$); significance was approached for Baseline 2 ($p = .084$).

Respiratory Sinus Arrhythmia

RSA reflects the interface between heart rate interbeat interval and respiration. Heart rate increases with inhalation and decreases with exhalation, and RSA takes into account the variability in HR, accounting for changes due to respiration (Grossman & Taylor, 2007). The unit of measure is milliseconds. The results show that RSA differed significantly across epochs, $F(4.16, 23.46) = 75.77$, $p = .013$. The effect of gender on the model was nonsignificant ($p = .871$). RSA was highest, indicating an increase in parasympathetic function, during the Vayu Vest epoch ($M = 6.694$, $SD = 0.95$; Figure 4). Post hoc tests using the Bonferroni correction revealed that the Vayu Vest epoch differed significantly from Test 1 ($p < .05$), Baseline 3 ($p < .05$), Test 2 ($p < .05$), and recovery ($p < .05$); significance was approached for Baseline 2 ($p = .057$).

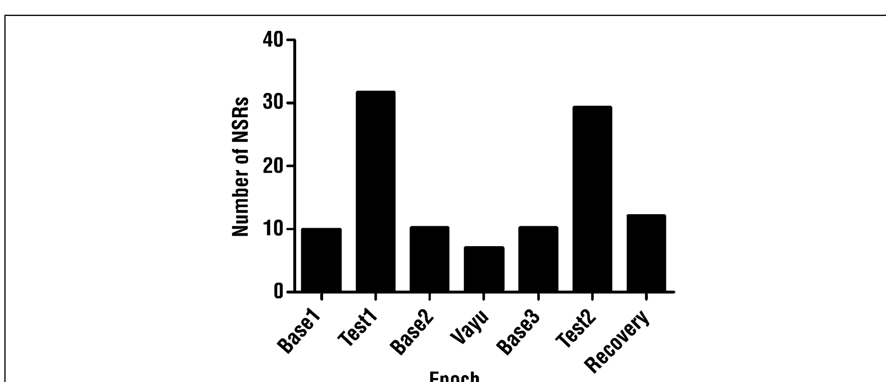

Figure 3. Number of NSRs across epochs.
Note. All epochs were 3 min in length. Base1 = Baseline 1 epoch; Base2 = Baseline 2 epoch; Base3 = Baseline 3 epoch; NSRs = nonspecific skin conductance responses; Recovery = final epoch, or final baseline data collection point; Test1 = first administration of Moron Test; Test2 = second administration of Moron Test; Vayu = epoch when Vayu Vest was inflated.

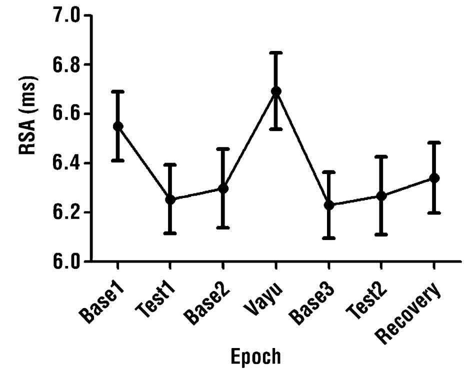

Figure 4. RSA across epochs.
Note. Error bars indicate standard error of the mean. All epochs were 3 min in length. Base1 = Baseline 1 epoch; Base2 = Baseline 2 epoch; Base3 = Baseline 3 epoch; Recovery = final epoch, or final baseline data collection point; RSA = respiratory sinus arrhythmia; Test1 = first administration of Moron Test; Test2 = second administration of Moron Test; Vayu = epoch when Vayu Vest was inflated.

Performance Outcomes

There was a significant difference in the number of errors made during Test 1, $M = 5.912$, $SD = 2.67$, and Test 2, $M = 3.75$, $SD = 2.24$; $t(47) = 6.661$, $p < .001$. These results suggest that performance improved after wearing the Vayu Vest.

Discussion

All three hypotheses proposed in this study were supported. Wearing the inflated Vayu Vest, for even short periods of time (3 min), resulted in reduced arousal after a stressor (engagement in the Moron Test) as reflected in sympathetic measures. This finding is consistent with our previous research in which sympathetic measures of arousal were positively correlated with measures of anxiety in children (Lane, Reynolds, & Dumenci, 2012). In addition, inflation of the vest after the stressor resulted in concomitant increases in parasympathetic activity, leading to an overall autonomic response that was calming to participants. This shift in both sympathetic and parasympathetic nervous system activity after deep pressure was applied to the thorax for a very short period of time has not been previously documented.

It is of interest that such changes could be induced in a typical population, in which elevated arousal was not evident at baseline. Although removal of the stressor (Moron Test) was sufficient to reduce arousal and increase parasympathetic activity, short-term use of the Vayu Vest enhanced these responses. We had chosen the 3-min epoch partially out of convenience, but this choice was supported by anecdotal reports received before this study that the vest produced a quick "sense" of calm. In querying participants at the end of the study regarding how they liked the vest, some reported almost immediate calming effects; others indicated that a longer wear time might have reduced arousal too much.

In considering the application of this intervention to children, and to people with disabilities that involve arousal regulation (e.g., autism spectrum disorder [ASD]), we will need to carefully examine administration dose. It is known that children respond to acute stress more slowly than do adolescents and adults (cf. Hare et al., 2008), suggesting that longer wear times for children may be needed. Because we did not apply the vest during test performance, it is not possible for us to determine whether this timing of administration would have produced a different effect on performance. Timing then is also in need of additional investigation.

The primary limitation in this study was the use of a nonstandardized performance measure. However, although the Moron Test is unstandardized, it does require sustained attention, problem solving, quick response times, and response inhibition, thus providing a proxy for a more standardized attention or cognitive measure. The game is an engaging task, and it is difficult to know how it might or might not correlate with other, more standard assessments of attention and problem solving. Although results must be interpreted cautiously, the preliminary data indicate that performance is significantly improved after wearing the Vayu Vest, potentially because of noted changes in arousal.

Empirical evidence, needed to support the use of deep pressure interventions, is lacking in the current literature. However, this study provides support for the foundational principal that deep pressure input to the thorax is capable of influencing autonomic arousal through reduction of sympathetic and enhancement of parasympathetic nervous system activity. These types of physiological measures should be considered for use in future experimental studies as a means of objectively assessing response to treatment in clinical groups. Specific to use of the Vayu Vest, feasibility studies are needed to establish parameters under which people with psychological disorders will don the vest and tolerate and manually regulate vest pressure. Optimal wear time parameters will also need to be established through systematic study.

Implications for Occupational Therapy Practice

Difficulty with arousal regulation and sensory modulation occurs in many diagnostic groups treated by occupational therapy practitioners. These groups include (but are not limited to) children and adults with ASD, ADHD, posttraumatic stress disorder, anxiety disorders, and depression (Champagne, 2011; Pfeiffer, Kinnealey, Reed, & Herzberg, 2005; Reynolds, Lane, & Gennings, 2010; Sergeant, 2000, 2005; Tomchek & Dunn, 2007). The results of this study have the following implications for occupational therapy practice:

- Deep pressure input may be an appropriate therapeutic modality to use with people with difficulty with arousal regulation and sensory modulation during or in preparation for functional tasks.
- Deep pressure may be useful for reducing maladaptive internalizing and externalizing behaviors, increasing attention to task, and reducing impulsivity, all of which would support the client's ability to successfully perform daily life activities and engage in appropriate social–emotional, motor, and organizational tasks. ▲

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